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TENTATIVE GUIDELINES FOR LEAN-CEMENT CONCRETE AND LEAN CEMENT-FLY ASH CONCRETE AS A PAVEMENT BASE OR SUBBASE

THE INDIAN ROADS CONGRESS

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TENTATIVE GUIDELINES FOR LEAN-CEMENT CONCRETE AND LEAN CEMENT-FLY ASH CONCRETE AS A PAVEMENT BASE OR SUBBASE

1. INTRODUCTION

Lean cement concrete and lean cement-fly ash concrete are semi-rigid materials having distinctly superior load dispersion characteristics as compared to conventional granular bases and sub-bases like water-bound macadam. As such a smaller thickness of these materials can be used to replace the conventional base and subbase courses in flexible and rigid pavement construction.

Besides superior load-spreading properties, lean cement concrete and lean cement fly ash concrete are resistant to softening action of water and can serve as a good working platform on softer foundations. These would be particularly useful as a base/subbase course in heavy rainfall areas, or in black cotton soil areas (when laid over lime stabilised black cotton soil). Lean cement-fly ash concrete may be used with advantage wherever good quality fly ash is available within economic lead. As these materials will enable reduction in thickness *vis-a-vis* granular base courses, they are specially suitable for areas where good quality hardstone for such base courses has to be obtained from long distances.

In lean cement concrete mixes, the cement paste is rather thin due to less quantity of cement. Addition of fly ash results in formation of cement-fly ash paste of thicker consistency, thereby improving the plasticity and adhesiveness of the mix and reducing the tendency to segregation. As disposal of fly ash from thermal power stations is a recognised national problem, use of lean cement-fly ash concrete as a structurally superior paving layer will also contribute towards relieving this problem.

These guidelines were approved by the Cement Concrete Road Surfacing Committee (personnel given below) in their meeting held at Bhopal on the 8th December, 1976.

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These were then processed by the Specifications and Standards Committee in their meeting held at New Delhi on the 16th May 1977 subject to certain modifications which on the authorisation of the Committee, were carried out by Dr. R.K. Ghosh, N. Sen and R.P. Sikka, assisted by Y.R. Phull, K.L. Sethi and K. Arunachalam. These were later approved by the Executive Committee and the Council in their meetings held on the 3rd January and 19th January, 1979 respectively.

2. THICKNESS DESIGN OF LEAN CEMENT CONCRETE AND LEAN-CEMENT FLY ASH CONCRETE BASE/SUBBASE LAYER

2.1. As Sub-base/Base Course in Flexible Pavement

2.1.1. As failure in case of semi-rigid materials is by tensile cracking, the CBR method of design is not strictly applicable. However, in the absence of an established procedure for the design of semi-rigid bases or subbases in composite construction, the thickness of lean cement concrete or lean cement-fly ash concrete layer may be designed for the present as per the CBR method of design, vide IRC : 37-1970 "Guidelines for Design of Flexible Pavements", using an equivalency factor of 1.50*. The thickness of the semi-rigid layer so obtained shall thereafter be checked for adequacy by calculating its ultimate load carrying capacity using Meyerhof equations.

**Note :* The actual equivalency factor for lean cement concrete/lean cement fly ash concrete will depend on its strength and other factors. Even though equivalency factors of 2.0—2.5 have been reported for compressive strength in the range of 40-60 kg/cm^2 suggested in these guidelines, a value of 1.5 is recommended as a measure of caution.

2.1.2. Since the lean cement/lean cement-fly ash concrete layer will extend on either side of the surface course, the edge condition of loading is unlikely to arise. Therefore for calculation for load carrying capacity, it should be adequate to consider the interior condition only, for which the Meyerhof equation is given below:

$$P_u = \frac{2\pi f h^2}{3\left(1 - \frac{a}{3l}\right)}$$

where P_u = ultimate load carrying capacity for interior loading condition, kg

l = radius of relative stiffness of the semi-rigid layer, cm

$$= \sqrt[4]{\frac{Eh^3}{12(1-u^2)k}}$$

E = modulus of elasticity of lean cement/lean cement fly ash concrete, kg/cm^2 ($0.50-0.75 \times 10^5$ kg/cm^2 in the vicinity of ultimate load),

h = thickness of the lean cement/lean cement-fly ash concrete layer, cm,

u = Poisson's ratio of lean cement/lean cement fly ash concrete (0.20—0.30),

k = modulus of subgrade reaction determined on top of the layer below lean cement/lean cement-fly ash concrete kg/cm^3,

a = equivalent radius of load distribution over the lean cement/lean cement-fly ash concrete layer, cm,

f = design flexural strength of lean cement concrete/lean cement-fly ash concrete in the field (one-sixth to one-eighth of compressive strength).

2.1.3. To allow for load repetition during the design life of the pavement, the ultimate load carrying capacity, P_u, should be higher than the design wheel load, P. The values of load factor (P_u/P) recommended for the purpose are given in Table 1.

TABLE 1

Design load repetitions in terms of 8200 kg Standard Axle Loads	10^4	10^5	10^6	10^7	10^8	10^9
Load Factor	1.50	1.58	1.67	1.76	1.88	2.00

2.1.4. Temperature stresses may not be considered in this case, since the base/subbase course layer is protected by the overlaying pavement layers. Thickness of lean cement/lean cement fly ash concrete layer, should, however, in no case be less than 10 cm.

2.1.5. An illustrative example of thickness design for lean cement/lean cement-fly ash concrete base in flexible pavement is given in *Annexure I*.

2.2. As Subbase Course under Rigid Pavement

The thickness of lean cement concrete or lean cement-fly ash concrete layer for use as a subbase course under cement concrete pavement should be as per IRC: 15-1970, "Standard Specifications and Code of Practice for the Construction of Concrete Roads (First Revision)". IRC: 15-1970 recommends the provision of 10 cm thickness of lean cement concrete subbase in lieu of 15 cm thickness of water bound macadam.

2.3. The strength requirement of lean cement concrete/lean cement fly ash concrete shall be as given in para 4.1.

3. MATERIALS FOR LEAN-CEMENT CONCRETE AND LEAN CEMENT-FLY ASH CONCRETE

3.1. Cement

Cement for use in lean cement concrete or lean cement fly-ash concrete should conform to the requirements of IS: 269-1976: "Specifications for Ordinary, and Low Heat Portland Cement (Second Revision)" or IS: 1489 "Specifications for Portland Pozzolana Cement" or IS: 455-1967 "Portland Blastfurnace Slag Cement (Second Revision)". The use of portland pozzolana cement should, however, be restricted to lean cement concrete only. It should not be used in case of lean-cement fly ash concrete.

3.2. Fly Ash

Fly ash should conform to IS: 3812 (Part II) 1966, "Standard Specifications for Fly Ash, Part II, For Use as Admixture for Concrete". The lime reactivity should not be less than 40 kg/cm^2, fineness not less than 2800 cm^2/gm, and carbon content not more than 12 per cent.

3.3. Aggregates

Coarse aggregate for use in lean cement concrete or lean cement-fly ash concrete should be either natural stone aggregate conforming to IS: 383-1970: "Standard Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete (Revised)", or broken brick conforming to IS: 3068-1965: "Specification for Broken Brick Coarse Aggregate for Use in Lime Concrete", or cinder aggregate conforming to IS: 2686-1964: "Specifications for Cinder Aggregate for Use in Lime Concrete", depending upon the situation of use. Fine aggregate should conform to IS: 383-1970, or IS: 3182-1967: "Specification for Broken Brick Fine Aggregate for Use in Lime Mortar". Aggregate conforming to IS: 2686-1964 and having the required grading for fine aggregate as stipulated in IS: 383-1970 may also be considered. In selecting the aggregates, strength requirement stipulated in para 4.1. should be kept in view.

The maximum nominal size of the aggregate should not exceed 40 mm nor should it be less than 20 mm. The overall grading of aggregate should be within the limits given in Table 2.

TABLE 2

I.S. Sieve size	Per cent passing (by weight)	
	Nominal maximum size 40 mm	Nominal maximum size 20 mm
80 mm	100	—
40 mm	95—100	100
20 mm	45— 60	80—100
4.75 mm	30— 40	35— 45
600 μ	8— 30	10— 35
150 μ	0— 6	0— 6

3.4. Water

Water used in mixing or curing of concrete should be clean and free from injurious amounts of deleterious matter. Potable water is generally considered satisfactory for this purpose.

4. PROPORTIONING OF LEAN CEMENT CONCRETE AND LEAN CEMENT-FLY ASH CONCRETE

4.1. Mix Design Criteria

4.1.1. To act as a semi-rigid pavement layer, lean cement concrete/lean cement-lime fly ash concrete should be designed to give a minimum compressive strength of 40-60 kg/cm^2 at 28 days in the field.

As compaction in the field is to be done by rolling, workability shall be kept low, with 0-12 mm slump.

4.1.2. Having regard to process variances in the field, the laboratory mix should be designed for 1.25 times the required 28 days field strength.

4.2. Mix Design

4.2.1. The mix proportions for lean cement concrete and lean cement fly ash concrete are designed by trial and error method. To facilitate selection of suitable proportions of the trial mix, particulars for a few such concrete mixes, designed with fly ash conforming to IS: 3812 (Part II)-1966 "Specifications for Fly Ash for Use as Admixture for Concrete", medium coarse sand, and good quality crushed coarse aggregate of 20 mm max. size are given in Tables 3 and 4.

4.2.2. The maximum size of the coarse aggregate in the mix is limited by the thickness of the lean cement concrete or lean cement fly ash concrete layer to be laid, and should generally not exceed 40 mm for 10 cm layer thickness. While selecting trial, mix proportions from Table 3 or 4, allowance should be made for change in the maximum size and shape of aggregate, as increase in the maximum size of aggregate and its surface area requires reduction in water content; change from angular (crushed aggregate) to rounded (uncrushed gravel) shape requires reduction in both water and sand contents; and increase or decrease in fineness modulus of sand requires a like change in sand content. Significantly, lower strength may be expected when aggregates such as broken brick or cinder are used.

TABLE 3. PARTICULARS OF TYPICAL LEAN CEMENT CONCRETE MIXES

Sl. No.	Mix Proportions (by wt.)			Water Cement Ratio	Slump (mm)	28 day compressive strength (kg/cm)^2
	Cement :	Sand :	Coarse Aggregate			
1.	1 :	4 :	8	1.17	12	72.0
2.	1 :	5 :	10	1.73	12	53.0
3.	1 :	6 :	12	1.85	12	49.0
4.	1 :	7 :	14	1.88	12	37.0

TABLE 4. PARTICULARS OF TYPICAL LEAN CEMENT-FLY ASH CONCRETE MIXES

Sl. No.	Mix Proportions (by wt.)				Water Cement Ratio	Slump (mm)	28 day compressive strength (kg/cm^2)
	Cement :	Sand :	Fly Ash :	Coarse Aggregate			
1.	1 :	2 :	2 n :	8	1.32	12	158.0
2.	1 :	2.5 :	2.5 n :	10	1.90	12	130.0
3.	1 :	3 :	3 n :	12	1.98	12	100.0
4.	1 :	3.5 :	3.5 n :	14	2.20	12	102.0

n=ratio of specific gravities of fly ash and sand
=0.827 in this case.
Min. lime reactivity of fly ash=35 kg/cm^2

TABLE 5. QUALITY CONTROL TESTS

Sl. No.	Test	Test Method	Minimum desirable frequency
1.	Quality of cement	IS:269/455/1489	Once initially for approval of the source of supply and later for each consignment of the material.
2.	Quality of Fly ash	IS:3812 (Pt. II)	—do—
3.	Los Angeles Abrasion Value/ Aggregate Impact Value	IS:2386 (Pt. IV)	One test per 200 m^3
4.	Aggregate gradation	IS:2386 (Pt. I)	One test per 100 m^3
5.	Aggregate moisture content	IS:2386 (Pt. III)	As required
6.	Control of grade, camber, thickness and surface finish	Vide Chapter 7 of IRC:SP: 11-1977	Regularly
7.	Strength of cubes (Two specimens for each age of 7 and 28 days)	IS:516	One test for 50 m^3

4.2.3. As a rough guide, for the stipulated 28 day compressive strength of 40-60 kg/cm², the approximate total aggregate/cement ratio will be in the range of 12-18 and water content about 9-11 per cent by weight of total dry materials, for lean cement concrete mixes, when crushed stone is used as coarse aggregate.

4.2.4. In case of lean cement-fly ash concrete, optimum strength is obtained by replacing about 50 per cent of sand by weight in conventional lean cement concrete mix by equal absolute volume of fly ash (vide Tables 3 and 4). The water content requirement in this case is increased by about 1 per cent, and the strength obtained is more than double *vis-a-vis* the corresponding lean cement concrete mix. The following procedure may, therefore, be adopted to obtain mix proportions for lean cement fly ash concrete:

(1) Select lean cement concrete mix corresponding roughly to 50 per cent of the strength requirement for lean cement-fly ash concrete (vide Table 3). Let this mix be 1:x:y (cement: sand: coarse aggregate) by weight, with a water content of w% by weight of total aggregate.

(2) Corresponding mix for lean cement-fly ash concrete may be taken as:

1: (1-p) x: pxn:y (cement:sand:flyash: coarse aggregate),

Where n=ratio of specific gravity of flyash and sand,

p=proportion of sand by weight in the lean cement concrete mix to be replaced by flyash, on equivalent absolute volume basis. As a broad guide, a value of 0.5 might be adopted for p.

(3) The water requirement in this case will be about (w+1)% by weight of total aggregate. Perform trial slump test using this water content. Adjust the water content to obtain the desired slump (0-12 mm). Let the adjusted water content be w%.

(4) Similarly, determine water content requirement for two additional trial mixes

$$1:(1\text{-}p)\,(x\text{-}1) : p(x\text{-}1)\,n:y \left(\frac{x\text{-}1}{x}\right)$$

and

$$1:(1\text{-}p)\,(x+1) : p(x+1)\,n:y \left(\frac{x+1}{x}\right)$$

(5) Cast test cubes for determination of compressive strength for all the three trial mixes, and select appropriate design mix from the strength results.

Very approximately, the ratio of total aggregate (including fly ash) to cement will be in the range of 18-22, and water requirement in the range of 10-12 per cent by weight of total dry materials, for the stipulated 28 day compressive strength in the range of 40-60 kg/cm^2, when crushed stone is used as coarse aggregate.

5. EQUIPMENT

5.1. Batching and Mixing Equipment

Batching of materials for lean cement concrete/lean cement-fly ash concrete should be done by weight, and volume batching may be permitted only when unavoidable. Mixing should be done in power driven concrete mixers of adequate capacity. The stipulations of IRC: 43-1972 "Recommended Practice for Tools, Equipment and Appliances for Concrete Pavement Construction" in respect of weight batchers and mixers should be followed.

5.2. Compacting Equipment

Compaction of lean cement concrete/lean cement-fly ash concrete layer in the field should be done by means of an 8 to 10 tonne smooth wheel roller for harder aggregates (like stone metal) and 6-8 tonne roller for softer aggregates (like brick aggregate or cinder). Alternatively, vibratory rollers of equivalent capacity may also be used.

6. PREPARATION OF THE SUBGRADE/SUBBASE

6.1. The subgrade or subbase over which the lean cement concrete/lean cement-fly ash concrete layer is to be laid, should be checked for line, grade and cross-section, vide Chapter 7 of IRC:SP: 11-1977, "Handbook of Quality Control for Construction of Roads and Runways (First Revision)". All irregularities beyond the permitted tolerance should be rectified. Soft and yielding spots and ruts, if present, should be corrected and rolled until firm. The checking and rectification of the underlying layer should be done at least 2 days in advance of laying lean cement concrete/lean cement fly ash concrete.

6.2. To prevent absorption of water from lean cement concrete/lean cement-fly ash concrete, the underlying layer should either be covered with water proof paper or brought to moist condition

without free water at the surface before laying the former. For this purpose, the underlying layer may be saturated with water 6 to 20 hours in advance, followed by light sprinkling of water prior to laying of the semi-rigid layer, if any areas have become dry.

7. CONSTRUCTION

7.1. Storage and Handling of Cement

The provisions in clause 8.1 of IRC: 15-1970: "Standard Specifications and Code of Practice for the Construction of Concrete Roads" should be followed as regards storage and handling of cement.

7.2. Storage and Handling of Fly Ash

Fly ash, being light and very fine, gets easily air borne. As a precautionary measure, it may be bagged, suitably covered, or soaked with water at the top during transportion. When not bagged, it may be stored in regular trapezoidal pits dug for the purpose. The top surface may be either kept wet or covered with tarpaulin.

7.3. Storage and Handling of Aggregates

The provisions in clause 8.2 of IRC: 15-1970: "Standard Specifications and Code of Practice for the Construction of Concrete Roads", should be followed in respect of storage and handling of aggregates.

7.4. Batching and Mixing of Materials

7.4.1. The marerials for making lean cement concrete/lean cement-fly ash concrete mix should be batched by weight using approved weigh-batching equipment. Volume batching may be permitted only when unavoidable. Water may be measured by volume, using calibrated containers. Proportioning of the constituent materials should be on the basis of designed mix proportions, making due allowance for moisture present in fly ash and aggregates. While loading the mixer, water should be added first, cement and fly ash next, and aggregates the last.

7.4.2. Mixing should be done in power driven mixers of approved type, and uniform homogenous mixing of all the ingredients shall be ensured. The mixer should not be overloaded, and adequate mixing time (1-2 min.) should be allowed to ensure uniform mixing.

7.5. **Transportation and Placement**

The lean cement concrete/lean cement-fly ash concrete should be transported and so placed on the prepared subgrade/subbase so that the compacted layer has the required depth, slope and camber. The amount of surcharge required is about 20-25 per cent of the thickness of layer to be laid. The actual amount of surcharge may be determined through field trial. Transportation and placement should be so done as to avoid segregation. Any portion of the batch which becomes segregated during placing, should be thoroughly mixed with the main body of the batch during the process of spreading.

7.6. **Compaction**

7.6.1. When sufficient length of lean cement concrete/lean cement-fly ash concrete has been laid to permit rolling, compaction should be commenced (see para 5.2). Rolling should start from the outer edges of the pavement and proceed towards the middle except at superelevated portions where it should commence at the lower edge and proceed towards the higher. Adequate number of passes shall be given to ensure full compaction. Eight passes are generally considered adequate for the purpose.

7.6.2. The grade and camber of the surface should be checked during compaction, and all irregularities should be corrected by removing or adding fresh material.

7.6.3. Compaction should be completed within a specified period which shall not exceed 45 minutes in summer and 1 hour in winter after mixing. The maximum thickness to be compacted in a single layer should not exceed 10 cm in case of smooth wheel rollers and 15 cm in case of vibratory rollers of equivalent capacity (vide para 5.2). When lean cement concrete/lean cement-fly ash concrete is to be laid in more than one layers, each subsequent layer should be laid within one hour of compaction of the preceeding layer.

7.7. **Joints**

No joints need be provided except construction joints at the end of the day's work. These shall be formed by chamfering the edge of the already laid layer at an angle of about 30° to the vertical.

7.8. **Curing**

After laying and compaction of the total thickness of lean

cement concrete/lean cement-fly ash concrete, it should be cured for the first 48 hours by covering it with wet gunny bags or hessian and for a further period of not less than 12 days by spreading wet sand or watering frequently in moderate quantities. Curing by ponding is not necessary. No traffic should be allowed on this layer before top courses have been laid.

7.9. Rectification of Surface Irregularities

The finished surface should be checked for line, level, grade and surface finish. Provisions in Chapter 7 of IRC:SP: 11-1977 "Handbook of Quality Control for Construction of Roads and Runways (First Revision)" should be followed for this purpose. The checking and rectification of the surface, if required, should be carried out while the mix is still plastic. Any surface irregularities left in the hardened layer should be corrected by cutting out sufficiently large patches and relaying to specification.

8. SURFACE COURSE

8.1. Lean cement concrete and lean cement-fly ash concrete, being semi-rigid materials, may develop transverse cracks on account of thermal effects/drying shrinkage. These cracks are likely to get reflected on to the wearing surface if this semi-rigid layer is overlaid, with a thin bituminous wearing course (e.g. surface dressing or premix). To prevent such reflection cracking, when lean cement concrete/lean cement-fly ash concrete is used in composite pavement construction, it is recommended that an intermediate layer of water bound macadam, or bituminous macadam should be incorporated before providing the wearing course, so as to absorb the movement at cracks in the semi-rigid layer, and to prevent their reflection on to the surface. Minimum thickness of this intermediate layer plus wearing course should not be less than 10 cm.

8.2. In case of rigid pavement, where lean cement concrete/lean cement-fly ash concrete is used as a subbase, the cement concrete wearing course can be laid directly thereon without provision of any intermediate layer, as due to greater rigidity of the cement concrete layer, cracks from the semi-rigid subbase do not get reflected.

9. QUALITY CONTROL

Quality control tests and their minimum desirable frequency should be as given in Table 5.

Annexure I

AN ILLUSTRATIVE EXAMPLE OF THICKNESS DESIGN FOR LEAN CEMENT/LEAN CEMENT FLY ASH CONCRETE BASE IN FLEXIBLE PAVEMENT

1. Design Parameters

Design wheel load, P	$=4100$ kg
Present Traffic Intensity	$=300$ veh/day
Design tyre pressure	$=5.8$ kg/cm²
Subgrade CBR	$=5$
Modulus of subgrade reaction, k	$=2.8$ kg/cm³

Equivalency factors in terms of granular construction:

Lean cement/lean cement fly ash concrete	$=1.5$
Bituminous macadam	$=2.0$
Asphaltic concrete	$=2.0$

Field mix design compressive strength of Lean cement/Lean cement fly ash concrete, $f_c=60$ kg/cm².

2. Design Procedure

Step 1. Design traffic intensity for flexible pavement at traffic growth rate of 7.5% and design life of 10 years (vide IRC-37)

$T=300\,(1+0.075)^{10}$

$=300\times 2.06$

$=618$, which falls under traffic classification E.

Following Curve E of CBR curves for flexible pavement design (IRC: 37-1970), the total thickness of construction required over the compacted soil of CBR 5 works out as 45 cm.

Step 2. Assuming minimum cover of 10 cm bituminous macadam and 4 cm A.C. over the lean cement/lean cement-fly ash concrete base.

Equivalent granular construction thickness over lean cement/lean cement fly ash concrete

base$=10\times 2.0+4\times 2.0=28.0$ cm.

Step 3. Radius of load dispersion on Lean cement/Lean cement-fly ash concrete base,

a=radius of contact at surface+thickness of equivalent granular construction over the base

$$=\sqrt{\frac{4100}{\pi\times 5.8}}+28.0=15.0+28.0$$

$=43.0$ cm

Step 4. For ensuring a minimum load factor of 1.67, the required ultimate load carrying capacity of lean cement fly ash concrete base.

$P_{umin}=1.67=4100\times 1.67=6850$ kg

Assuming $h=16$ cm

and taking $f=\frac{1}{6}\times f_c=\frac{1}{6}\times 60$

$=10$ kg/cm^2

$E=0.5\times 10^5$ kg/cm^2

$u=0.25$,

radius of relative stiffness 1 is equal to

$$1=\sqrt[4]{\frac{E\,h^3}{12\,(1-u^2)\,k}}=\sqrt[4]{\frac{(0.5\times 10^5\times 16\times 16\times 16)}{12\,(1-0.25^2)\times 2.8}}$$

$=50.2$ cm

$$\therefore \frac{a}{1}=\frac{43.0}{50.2}=0.855$$

$$P_u=\frac{2\,\pi f\,h^2}{3\left(1-\frac{a}{31}\right)}=\frac{2\,\pi\times 10\times 16\times 16}{3\left(1-\frac{1}{3}\times 0.855\right)}$$

$=7500$ kg$>P_{umin}$

$h=16$ cm may be taken as the minimum design thickness of lean cement/lean cement fly ash concrete base.

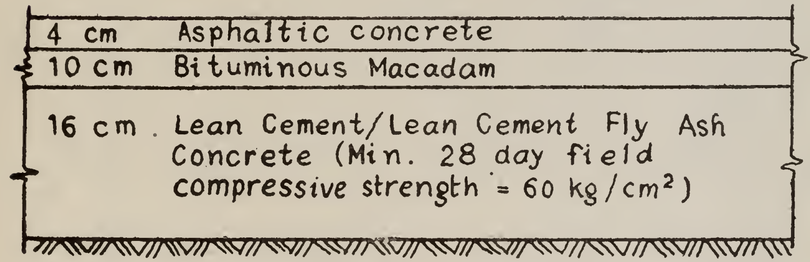
Step 5. Total equivalent granular thickness of lean cement/lean cement fly ash concrete base and bituminous cover thereon, taking an equivalency factor of 1.50 for lean cement/lean cement fly ash concrete.

$=16\times1.5+28.0$

$=24.0+28.0=52.0$ cm

which satisfies the design thickness requirement over compacted subgrade as per CBR criteria.

Summary: The design section of flexible pavement with lean cement fly ash concrete base, is, therefore, as given below:



Compacted soil subgrade CBR = 5